Atomic Parity Nonconservation in Stable Ytterbium Isotopes

D. Budker,[1,2] S. J. Freedman,[1,2] J. E. Stalnaker,[1,2] and Valeriy Yaschuk[1]

[1]*Department of Physics, University of California at Berkeley, Berkeley, California 94720-7300*

[2]*Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720*

The structure of atoms is dominated by the electromagnetic interaction between the nucleus and atomic electrons. However, there are small modifications to this structure from the weak interaction. By exploiting the parity-nonconserving (PNC) nature of the weak interaction, it is possible to isolate these effects; providing a unique system for probing the Standard Model of electroweak interactions.

The $6s^2\ ^1S_0 \rightarrow 6s5d\ ^3D_1$ in atomic Yb is a promising systems for the study of PNC [1]. In the absence of parity nonconservation, the electric-dipole (E1) transition amplitude is strictly forbidden by the parity selection rule, while the magnetic-dipole (M1) amplitude is highly suppressed. The application of an external electric field mixes even and odd parity states, giving rise to a Stark-induced amplitude ($\mathrm{E1_{St}}$). The weak interaction also mixes even and odd parity states, giving rise to a parity nonconserving amplitude ($\mathrm{E1_{PNC}}$). In order to measure the very small $\mathrm{E1_{PNC}}$, one observes the interference between the much larger $\mathrm{E1_{St}}$ and $\mathrm{E1_{PNC}}$, as one excites this forbidden transition with intense laser light. The parity-violating effect in Yb is expected to be very large, due to the presence of two energetically nearby states of opposite parity.

Comparing PNC effects in several stable isotopes of Yb will allow us to extract fundamental information about the weak interaction independent of the atomic structure calculations. In addition, comparison of PNC effects in the different hyperfine components of the two odd isotopes of Yb will allow for a determination of the nuclear anapole moment, a key quantity in improving our understanding of PNC effects within the nucleus.

In the past year we have completed a measurement of the highly forbidden M1 transition amplitude for the $6s^2\,^1S_0 \rightarrow 6s5d\,^3D_1$ transition through the method of Stark interference [2]. This quantity is important in understanding possible systematic errors for future PNC results. The measured value is

$$|\langle ^3D_1|M1|^1S_0\rangle| = 1.33(6)_{Stat}(20)_\beta \times 10^{-4}\ \mu_0,$$

where the second error represents the uncertainty in the determination of the Stark-induced amplitude β. The size of the M1 amplitude should not limit the precision of a PNC experiment.

We have also begun to develop a confocal power-build-up cavity with a build-up factor of ≈ 1000. This build-up factor will allow us to determine the optimal design for a future power-build-up cavity, as well as allow us to make a measurement of the PNC-induced transition amplitude to a fractional experimental precision of $\lessapprox 1\%$. We have succeeded in coupling our laser source at $408\,nm$ into the power-build-up cavity and locking the laser source to the cavity. Implementation of the power-build-up cavity and the associated laser stabilization and locking represent some of the largest technical challenges of the PNC experiment.

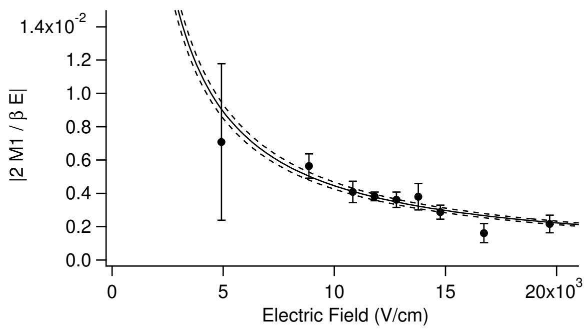

FIG. 1: Measured values of $\left|\frac{2M1}{\beta E}\right|$ as a function of $|\mathbf{E}|$. The solid line is the expected dependence from the overall mean and the dashed lines are the errors on the mean.

[1] D. DeMille, Phys. Rev. Lett. 74, 4165 (1995).

[2] J.E. Stalnaker, D. Budker, D. DeMille, S.J. Freedman, and V.V. Yashchuk, submitted to Phys. Rev. Lett. (2002).